

# NCSX Goals, Design Status, and Projected Plasmas

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for the NCSX Design Team

ICC-2000, Berkeley, CA  
22 February 2000

# The Compact Stellarator Design Team

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Germany, Switzerland, Russia, Japan, Australia, Spain**

## Stellarators Can Offer Innovative Solutions

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Can combine the best features of Stellarators and Advanced Tokamaks

- Stellarators:

*Externally-generated helical fields, low recirculating power,  
typically disruption free.*

**But:** High aspect ratio (5-12), low power density projected

- Advanced tokamaks:

*Excellent confinement, Bootstrap current*

**But:** Elaborate controls to avoid disruptions, Current drive;

high recirculating power ( $Q_{eng} \sim 5$ )

Advances in Theory and Numerical Design Capability      Compact Stellarators

- 3D shaping to stabilize external kink, vertical, neo-tearing; prevent disruptions
- Steady state without current drive.
- Aspect ratio: 3 – 4
- Good confinement. Quasi-axisymmetry to close drift-orbits, allow plasma flow

# National Compact Stellarator Experiment (NCSX)

## Research Goals

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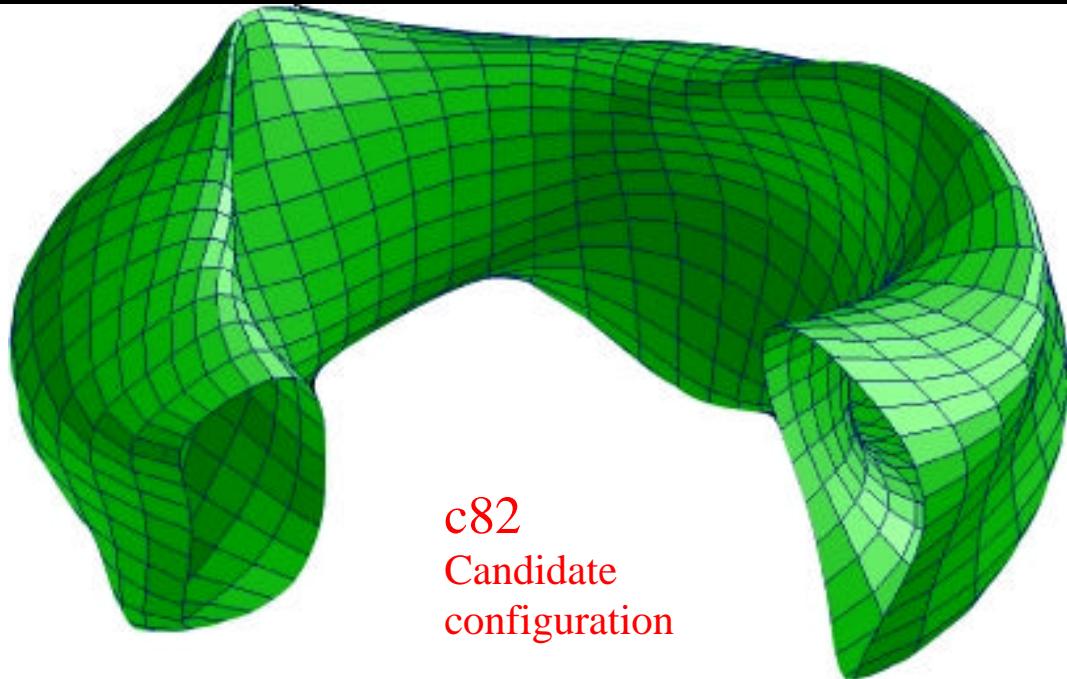
- High-beta disruption-free operation, compatible with bootstrap & external transform, at low aspect ratio ( $A < 4$ )
- Determine beta limits and limiting mechanisms
- Reduction of neoclassical transport by quasi-axisymmetric (QA) design
- Reduction of anomalous transport by flow-shear control, using reduced flow damping by QA design
- Equilibrium island and neoclassical tearing-mode stabilization by design of magnetic shear
- Test compatibility with power and particle exhaust methods



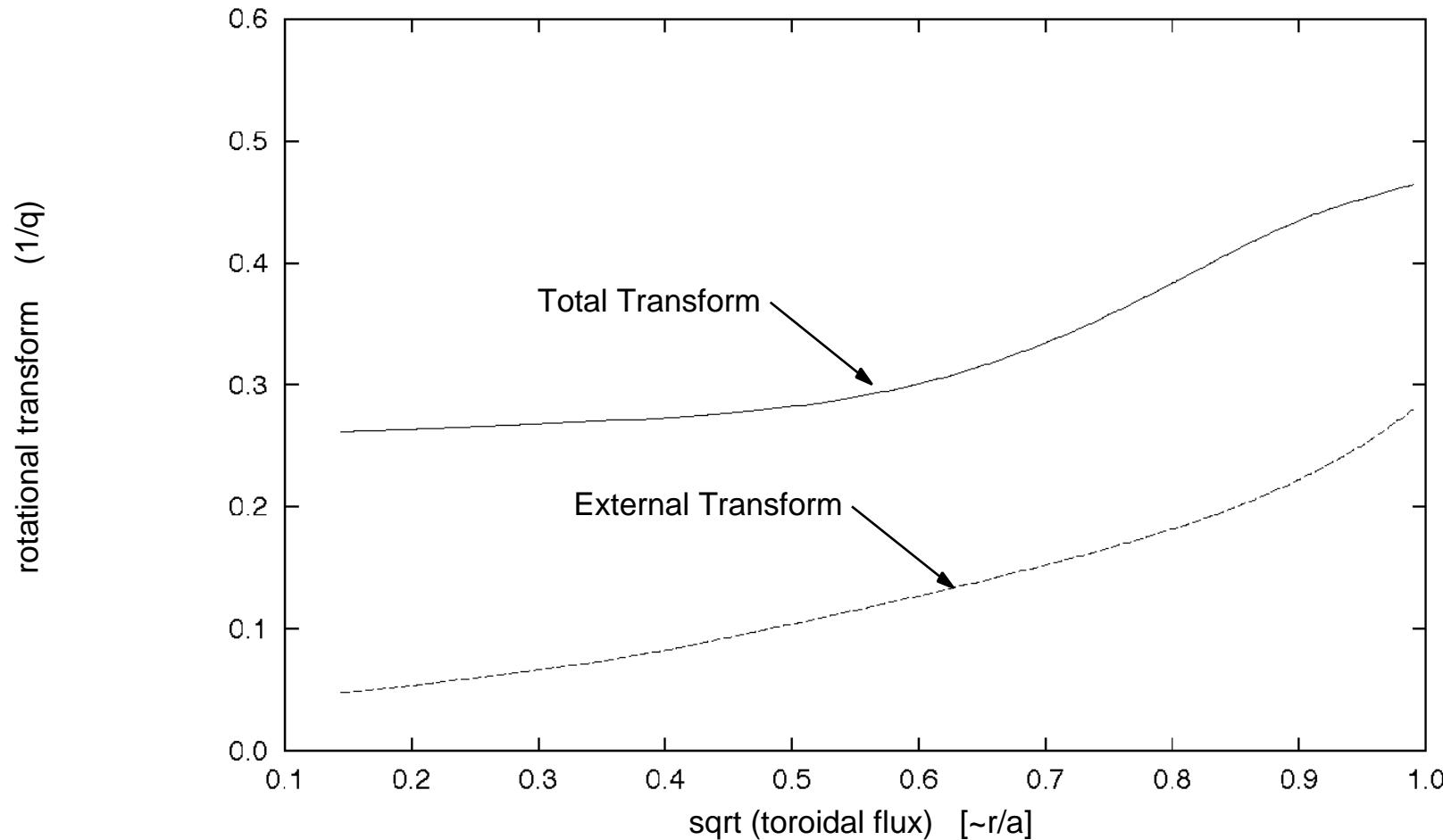
# NCSX Configuration Stable at $\beta = 4\%$

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- 3 periods,  $A = 3.4$ ,  
Quasi-axisymmetric
- Stable to ballooning, kink,  
vertical, mercier modes  
without conducting wall  
at  $\beta = 4\%$
- Bootstrap-like current profile, increases iota.
- Stellarator shear ( $dq/dr < 0$ ), for neoclassical island stabilization



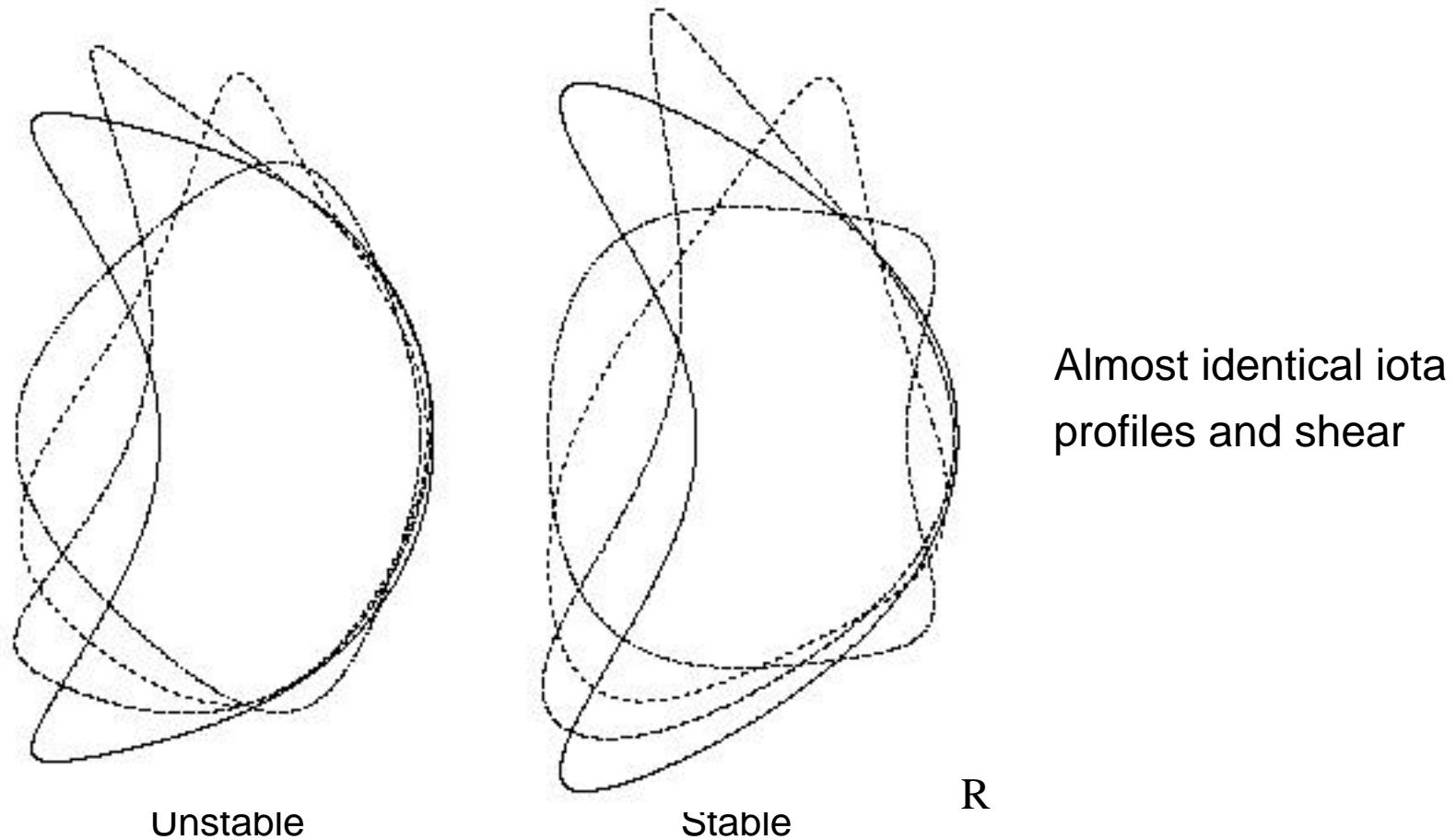
## NCSX Coils provide edge shear and ~50% of transform



- Edge iota does not cross 0.5
- Sufficient external transform to prevent disruptions in W-7A & Cleo

## Boundary Deformation To Stabilize External Kink

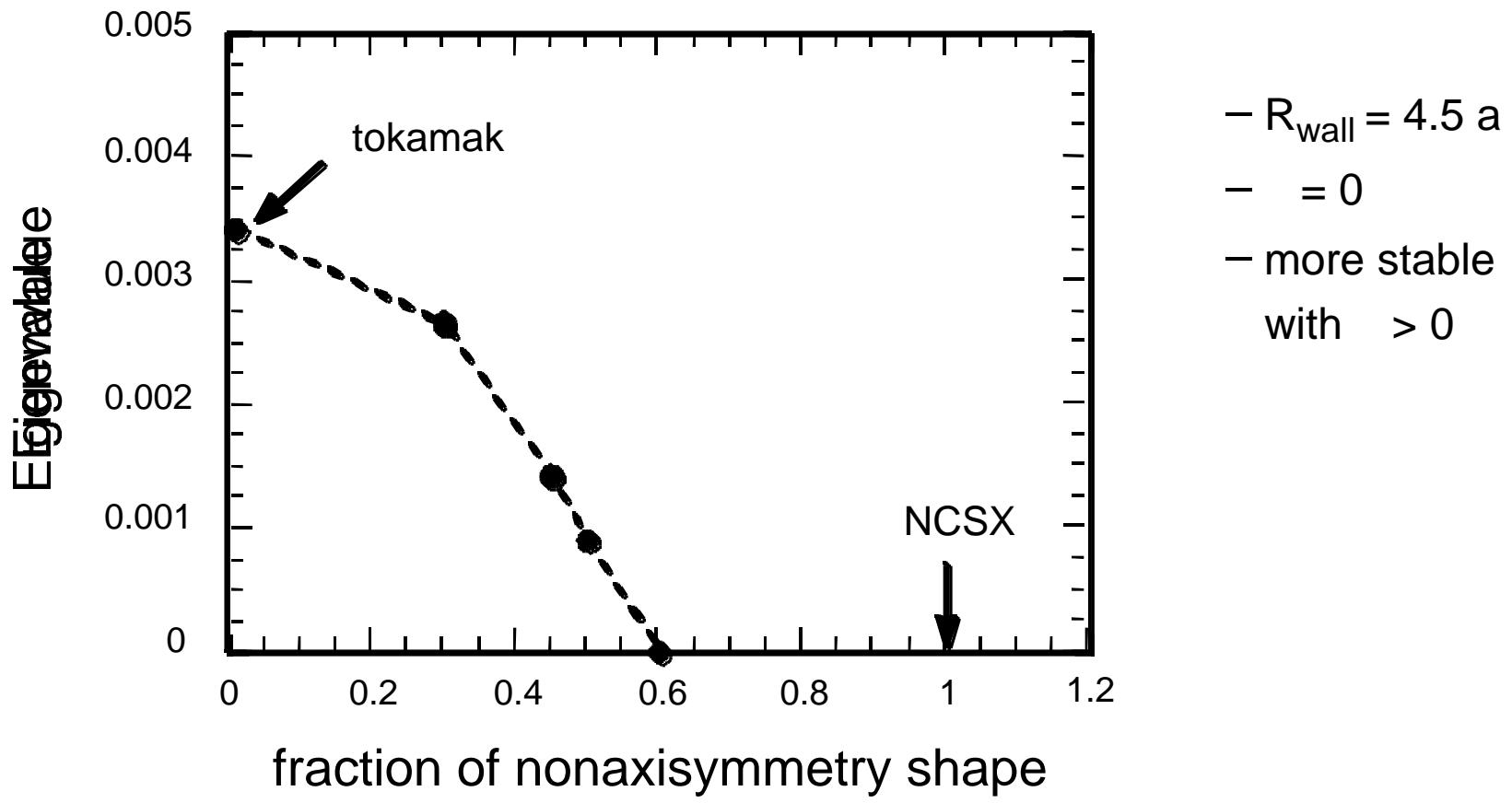
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- Kink also stabilized by significant edge magnetic shear
- Shape perturbation can be controlled with coils.

# External Transform from Stellarator Fields Stabilizes QA Vertical Instability

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- Required  $\frac{\partial}{\partial \theta} \psi_{ext}$  for stability increases with average elongation.

# NCSX Confinement Projections Using 3D Simulations

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## Neutral Beam Orbit Loss vs B

- 3D Monte Carlo orbit-following code with full collision operator.
- Co-injection  $H^0$   $H^+$  favored.

## Thermal Neoclassical Transport

- 3D gyrokinetic M-C code for electrons, ions.
- Assume  $e(a^-_0) = T_{i0}$  to approximate ambipolar  $E_r$  (ion root);  
increases confinement by ~30%.
- Neoclassical confinement time  $\propto B^2$ . Electron transport << ions.

## Operating Point Projections

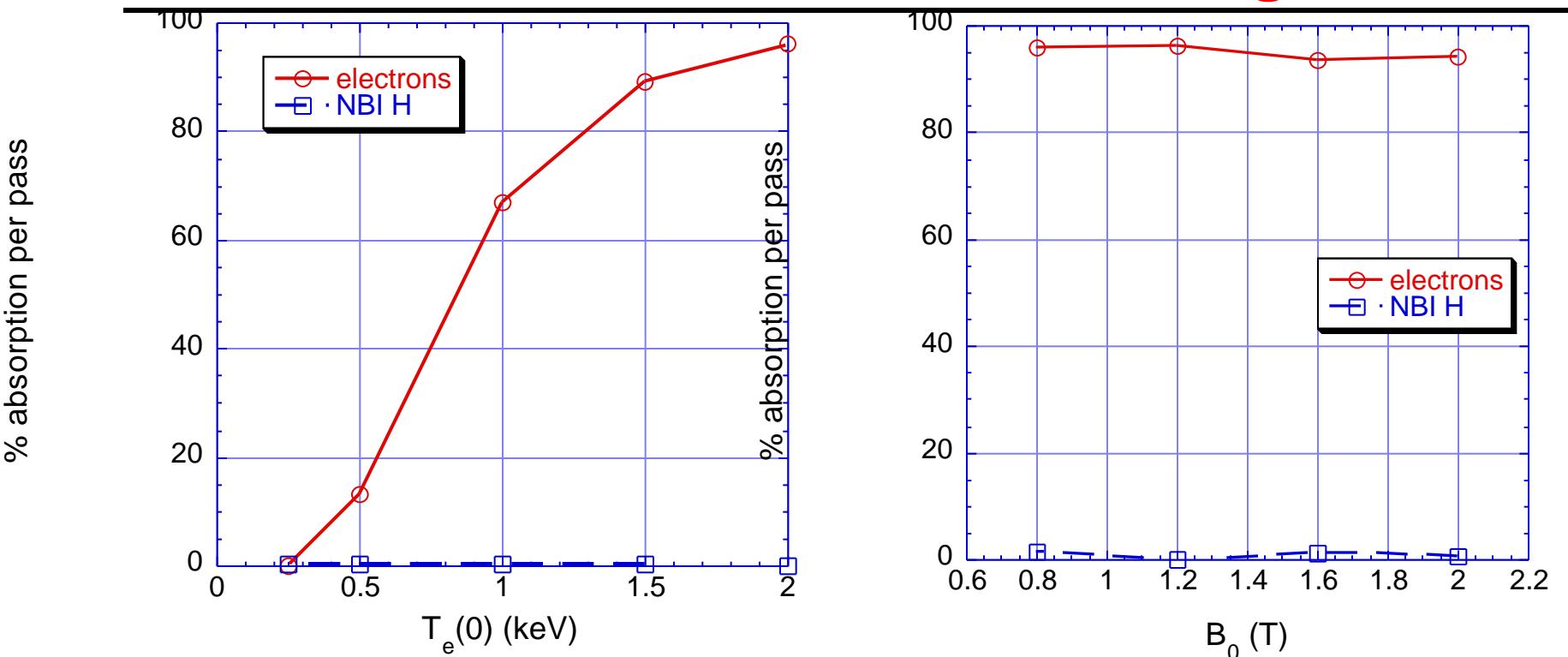
- take maximum confinement  $E$  as  $2.3 E^{ISS95}$  global scaling (~best on W-7AS)
- use  $E = \min(2.3 E^{ISS95}, E^{neo}/2)$ , anomalous losses ~ neo at best.

# Projected =4% Operating Point

C82, R=1.45 m, a =0.42 m, Z <sub>eff</sub> =2	
Magnetic field, B (T)	1.5
Injected power, P (MW)	6.9
Volume-avg. beta (%)	4.0
Volume-avg. density, n (10 <sup>19</sup> m <sup>-3</sup> )	11.3
Central temperature, T <sub>0</sub> (keV)	2.0
Collisionality	~3 x Reactor
τ <sub>Ei</sub> (ms)	53      ~ 1.6 x ITER89P

- E<sup>assumed</sup> = min(2.3 × E<sup>ISS95</sup>, E<sup>neo</sup>/2)
- NBI orbit losses per Monte Carlo calculations
- Neoclassical confinement times per gyrokinetic simulations.
- Density less than Sudo limit, by constraint.
- Includes 10% beam beta.
- In progress: improved confinement-optimization; RF heating scenarios.

# High Harmonic Fast Wave Absorption is Strong over Wide Parameter Range



350 MHz),  $N_{||} = 6.8$ , 2%NBI H,  $B_0 = 1.2\text{T}$

$n_e(0) = 6 \times 10^{19} \text{ m}^{-3}$  (parabolic $^{0.5}$ ),  $T_e(0) = T_i(0)$ ,

350 MHz,  $N_{||} = 6.8$ , 2%NBI H

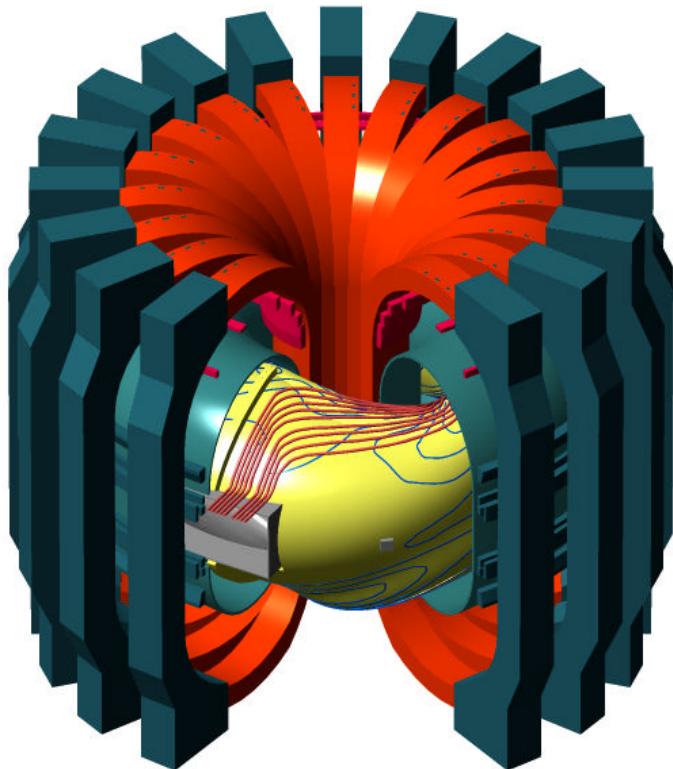
constant .

- Compact launchers; less sensitive to plasma position & shape

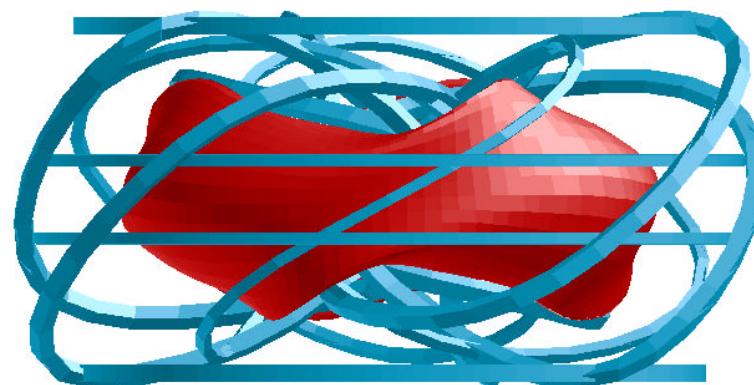
R. Majeski, Thurs. poster

## Optimized Coil Designs are Being Developed

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- Re-use PBX-M TF & PF coils
- New saddle coils for 3D fields



- Optimally shaped, helical & PF coils  
no saddles needed
- Better heating & diagnostic access

Analysis to compare flexibility & robustness beginning

G.H. Neilson, Wed. poster

## Near-Term Plans

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### Re-optimize design for all physics requirements

- Flexibility and startup
- Magnetic surface robustness and transport
- Coils and heating & diagnostic access

Using improved tools

### By September 2000

Establish stellarator configuration for Design Reviews

- Plasma
- Coils
- Machine construction concept

# Summary

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- NCSX will test whether a compact QA stellarator can operate disruption free at  $\beta \sim 4\%$
- NCSX has been designed to be passively stable to kink, ballooning, vertical, and neo-tearing instabilities.
- Transport assessments indicate that  $\beta = 4\%$  should be accessible (for c82) using 6.9MW of NBI.
- A number of interesting coil and machine designs have been developed. Physics benefits are being analyzed.